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# A BETTER LOADING PATTERN
# FOR
# TRAILER SHIPMENTS OF CITRUS FRUIT

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Marketing Research Report No. 715

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

## PREFACE

This study was conducted to develop an improved loading pattern for Florida citrus fruit packed in ⅘-bushel corrugated fiberboard boxes. Numerous firms and individuals provided assistance in the study. Cooperators included packinghouse operators, trade groups, railroads, truckers, brokers, and equipment suppliers. Special acknowledgment is made to the Corrugated Container Institute for its cooperation. The following members of the Transportation and Facilities Research Division helped conduct the tests: William F. Goddard, Kenneth Myers, William R. Black, and B. P. Rosanoff. General supervision was furnished by Philip L. Breakiron, Transportation and Facilities Research Division.

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Washington, D.C.

Issued September 1965

# SUMMARY

A new truck-trailer loading pattern of the airflow type was developed for citrus fruit packed in 4/5-bushel corrugated fiberboard boxes. This modified bonded-block pattern provides increased air circulation, resulting in more rapid and uniform cooling of fruit. The pattern was used for an estimated 90 percent of the 22 million corrugated boxes of Florida oranges and grapefruit shipped during the 1962–63 season.

The new pattern is sufficiently stable in transit to prevent container and product damage. It incorporates a series of connecting channels, that permit circulating air to reach each box of fruit in the load. It is suitable for both ventilated and refrigerated shipments in trailers on the highway and on railroad flatcars (piggyback).

Shipping tests with the pattern show average air velocities of 225 feet per minute in ventilated loads in trailers moving at 50 miles per hour and 250 feet per minute in refrigerated loads moving at the same speed. The reduction in fruit temperatures ranged from 11° to 33° F., depending upon the weather condition before and, to some extent, during shipment.

The pattern is easy for loaders to follow and can be adapted to trailers of different sizes. The spaces between the lengthwise boxes can be 2 to 3 inches, depending on the width of the trailer. The channels are formed by arranging the containers alternately two boxes lengthwise and two crosswise for the length of the trailer. This arrangement also ties the boxes together in a stable load that resists the disarranging effect of road shocks.

# A BETTER LOADING PATTERN FOR TRAILER[1] SHIPMENTS OF CITRUS FRUIT

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## BACKGROUND

The ⅘-bushel corrugated fiberboard box was first introduced to Florida shippers as a shipping container for fresh citrus fruit about 1948. The trade was slow to adopt the new containers. During the 1953–54 season only about 3 percent of the Florida oranges and grapefruit marketed fresh was packed in corrugated boxes. By the 1958–59 season, approximately one-third of the total shipments of fresh Florida oranges and grapefruit was packed in these boxes (*2,3*).[2]

Even though the corrugated box had been widely accepted, many shippers regarded it unsuitable for use during the entire season. Many tight-stacked loads of boxed citrus fruit shipped in warm weather arrived at northern markets with undesirably high temperatures. Cooling of the fruit in the interior of the tightly stacked loads was slow because the circulating air could not reach the containers.

Harvey and coworkers reported that "Oranges warm loaded in cartons may be expected to remain warm to destination regardless of the type of refrigeration service selected" (*5*). They also reported ". . . if satisfactory transit refrigeration were to be obtained, the load of cartons of nonprecooled oranges should be repatterned so as to permit better circulation of air through it" (*6*). It also has been found that some tight-stacked loads of grapefruit in fiberboard boxes shipped by piggyback show a temperature rise in the center of the load during transit (*8*).

Most Florida oranges and grapefruit are shipped without precooling. They are loaded at temperatures near or above the ambient temperature. Early and late in the shipping season, fruit temperatures often are in the upper 80's, while in midseason they range near 70° F. The U.S. Department of Agriculture recommends transit temperatures for citrus fruit well below these levels. The USDA recommends that Florida oranges be transported at 40° to 45° and grapefruit at 48° to 52° (*9*).

If best shipping results are to be obtained, the product should be cooled in transit by mechanical refrigeration or by use of cold outside air. Because moving air is the principal medium through which heat is removed from the fruit, the effectiveness of cooling is greatly influenced by circulation inside the trailer. To do a good job of cooling, cold air should be circulated to the warm fruit and then removed to dispose of the heat.

The rate of initial cooling and effective temperature maintenance in a given load depends on the temperature differential between the air and the product and on the volume of air moving through the channels. In ventilated loads, the temperature of the circulating air is the same as that of the outside air. The air volume is controlled by the speed of the vehicle and the size of the front and rear ventilation openings.

In refrigerated shipments, the ability to maintain a particular air temperature in the trailer is determined by the capacity of the mechanical unit or the amount of ice used and the adequacy of the air circulation system. The volume of air delivered to the cargo area depends on the size and speed of the fan and the air distribution system in the trailer.

Oranges and grapefruit often are transported as part of a mixed load of produce. Individual packages of the products may vary in size and number. These mixed loads are generally assembled in the trailer on a multiple-pickup basis, with each shipper loading his portion of the cargo in his allotted space. This type of load is difficult to arrange in an integrated unit for good air circulation and efficient cooling. Under the practices prevailing at the time this study was made, the packages were placed in the trailer with little provision for meeting the refrigeration requirements of the products.

Loading patterns for the corrugated box were modified several times in Florida between 1949 and 1959, but a satisfactory pattern was not developed. In 1959, this study was undertaken to design an improved loading pattern for the ⅘-bushel corrugated fiberboard box to provide better air circulation and more uniform cooling throughout the load during transit.

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[1] The general term "trailer" is used in this report to refer to semitrailers, full trailers, and trailers on railroad flatcar (piggyback).

[2] Italic numbers in parentheses refer to items in "Literature Cited," p. 8.

## REQUIREMENTS OF AN ACCEPTABLE LOADING PATTERN

Stacking patterns, the arrangement of boxes in a transport vehicle, are important in providing better air circulation and cooling in the load. Improper stacking may prevent uniform air circulation. As a result, fruit temperatures in different parts of the load may vary considerably.

A good stacking pattern for use in trailers should meet the following requirements:

1. It must be practical and not too complicated for the loaders to use.
2. It must lend itself to rapid stacking.
3. It must be readily adaptable to any size of trailer.
4. It must be compact enough to provide a full payload.
5. It must have adequate channels for air circulation throughout the load.
6. It must be sufficiently stable to remain intact during transit.
7. It must help prevent container failure and commodity damage.

## METHODOLOGY AND PROCEDURE

During a 2-year period, 30 shipping tests were conducted to develop a loading pattern that would give adequate air circulation in different types of trailers. Load stability, air circulation, cooling rates, temperature maintenance, and commodity and container damage were studied.

In some of the development work, researchers rode inside loaded trailers to measure air velocities and observe characteristics of the tight-stack pattern and other loading patterns in both refrigerated and ventilated loads. Air movement was measured by hot-wire and vane-type anemometers, and product and air temperatures were measured with thermocouples and stick thermometers.

## PATTERNS TESTED

The patterns studied were (1) chimney stack, (2) crosswise offset by layers, (3) alternate layers six and seven wide, (4) spaced vertical columns, and (5) spaced bonded-block.

More patterns were rejected for failure to provide adequate air circulation channels than for any other reason. The chimney stack pattern was too complicated for loaders to use, was not readily adaptable to different sizes of trailer, and did not have adequate channels for air circulation. The crosswise-offset-by-layers pattern was rejected because the air channels were inadequate. The pattern with alternate layers six and seven boxes wide was not compact enough, did not have adequate air channels, and did not protect containers and commodity. The spaced vertical column pattern was not compact enough, and the air channels were inadequate for good air circulation. Air channels were inadequate in the spaced bonded-block pattern, but this pattern met all the other requirements.

## THE MODIFIED BONDED-BLOCK PATTERN

After changes were made in the spaced bonded-block pattern to provide better air circulation, this pattern met all the requirements of a good stacking pattern. Originally, the spaced bonded-block pattern had no horizontal channels to promote air circulation. After the pattern was changed to provide lengthwise channels, it met all the requirements set forth in the preceding section more fully than before the change. With this airflow variation, the pattern can be adapted for ventilated or refrigerated shipments in trailers with either vertical or horizontal air circulation systems (fig. 1).

### Stacking Patterns

In refrigerated loads the boxes should be stacked with openings in the top layer (fig. 1A) so that refrigerated air can easily reach the center of the load. If the refrigerated trailers are equipped with sidewall ribbing, openings between boxes in the top layer must be provided. Previous research has shown that when this is not done, much of the refrigerated air from the ceiling duct will bypass the main body of the load by going down the spaces between the sidewall ribbing on its return to the refrigeration unit (*7*). The openings between the lengthwise boxes in the top layer permit the cool air from the ceiling duct to reach the channels in the lower part of the load, as shown in figure 2B.

When fruit is transported under ventilation, the top layer should be stacked tight by adding an extra box in each stack (figs. 1C and 2A). Tightly

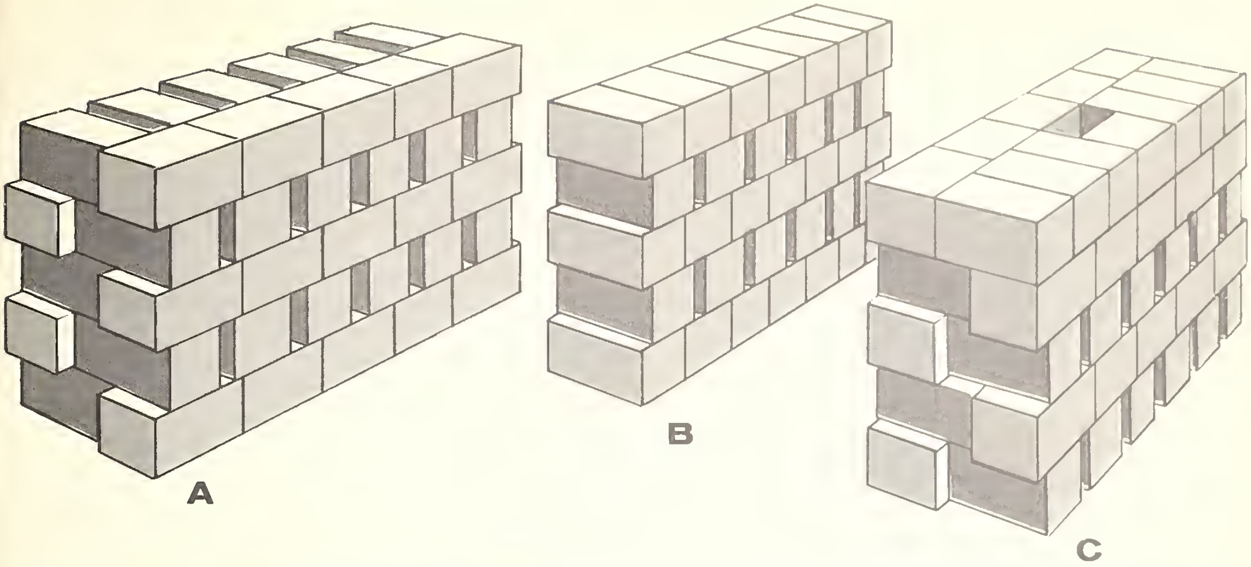


FIGURE 1.—Basic stacks for the new loading pattern. (A) Modified bonded-block stack (top layer open). (B) Lengthwise stack. (C) Modified bonded-block stack (top layer tight).

stacking the top layer from sidewall to sidewall forces the outside air, which enters the vehicle through the front vent door, to circulate through the center of the load before being exhausted through the rear vent doors. If the top layer in ventilated loads has openings, the circulating air will rise above the top of the cargo near the front of the load and move across the top of the load and out the rear vent doors. Thus, the effectiveness of the stacking pattern is not fully realized in cooling the center of the load.

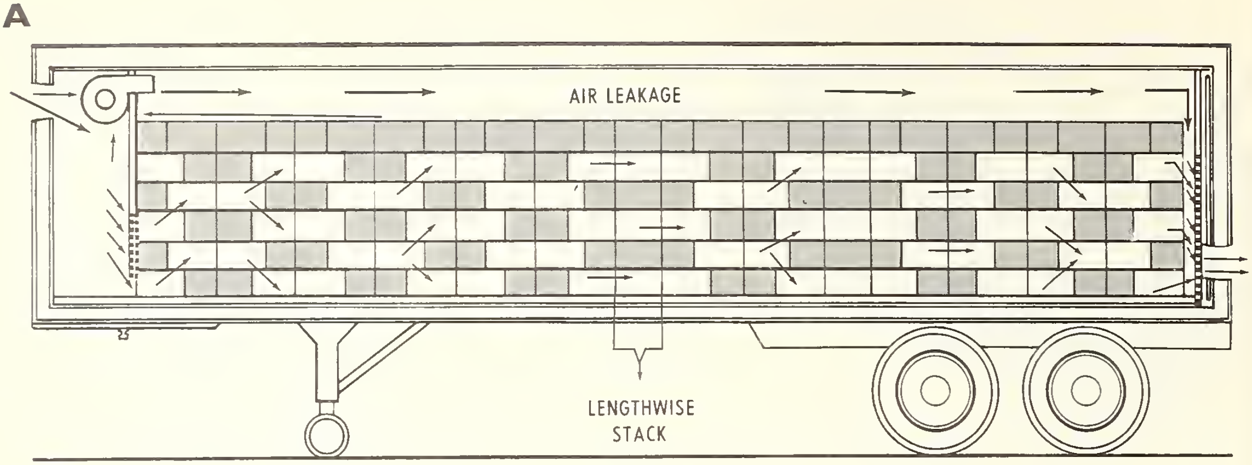
To adapt the load to trucks of different types and sizes, other variations of the modified bonded-block pattern may be used. For example, one or two of the lengthwise stacks shown in figures 1B and 2 can be used to make the pattern fit the length of the loading space in individual trucks. In the lengthwise stacks, all boxes are stacked lengthwise of the trailer; they are not interlocked with other boxes; and they are placed so the air channels match the air channels in the adjacent bonded stacks. These lengthwise stacks may be used anywhere in the load except at the rear; a regular modified bonded-block stack gives greater stability and resistance to the load-disarranging road shocks concentrated in this area of the trailer.

Most trailers used for fresh produce are equipped with 2 to 3 inches of insulation and have a loading width of about 90 inches, in which the basic pattern will fit quite well. The basic pattern must be varied for thicker insulation and for widths less than 90 inches.

## Loading the Pattern

The method by which the modified bonded-block pattern is laid off before loading is shown in figure 3. A guide row is placed along one sidewall to help the loader arrange the stacks in the proper sequence. Containers are arranged alternately two lengthwise and two crosswise, with 2- to 3-inch-wide air channels between the lengthwise boxes. Each stack has six rows of boxes placed lengthwise with five air channels between the rows and five rows of boxes placed crosswise with no air channels. The stack allows channels for air circulation between some containers on the sides of the load and the trailer's sidewalls. When these stacks are placed so the bottom boxes along the sidewalls are in the sequence of two lengthwise, two crosswise, two lengthwise, etc., a network of connecting air channels is formed (fig. 2). These channels permit the circulating air to reach each container in the load to give better cooling and more nearly uniform fruit temperatures. The incompleted stack in figure 4A illustrates the formation of the air channels. Figure 4B illustrates the completed stack and also the tight stacking of the top layer of the last two stacks to prevent load shifting at the rear of the trailer.

The basic design of this pattern can be used for packaged products other than citrus fruit. Slight variations may be required to fit boxes of different size into the available loading space. The system of connecting channels is required for agricultural commodities that require air circulation and temperature control.



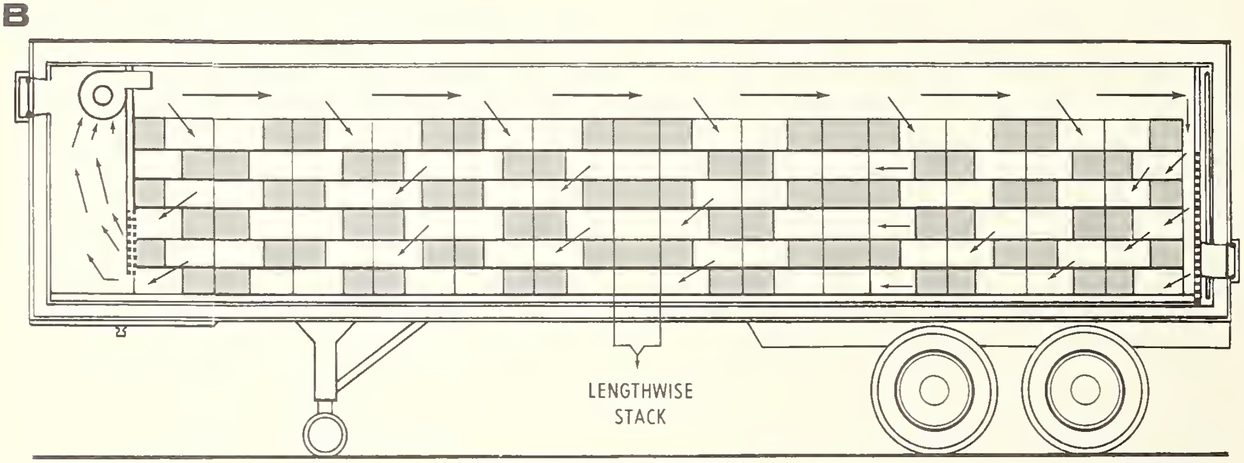


FIGURE 2.—Air channels and circulation patterns in modified bonded-block load. Lengthwise stacks (fig. 1B) are used to make the stacking pattern fit the length of the loading space. (A) Ventilated load—*tight* top layer, blower *off*, vent doors *open*. (B) Refrigerated load—*open* top layer, blower *on*, vent doors *closed*.

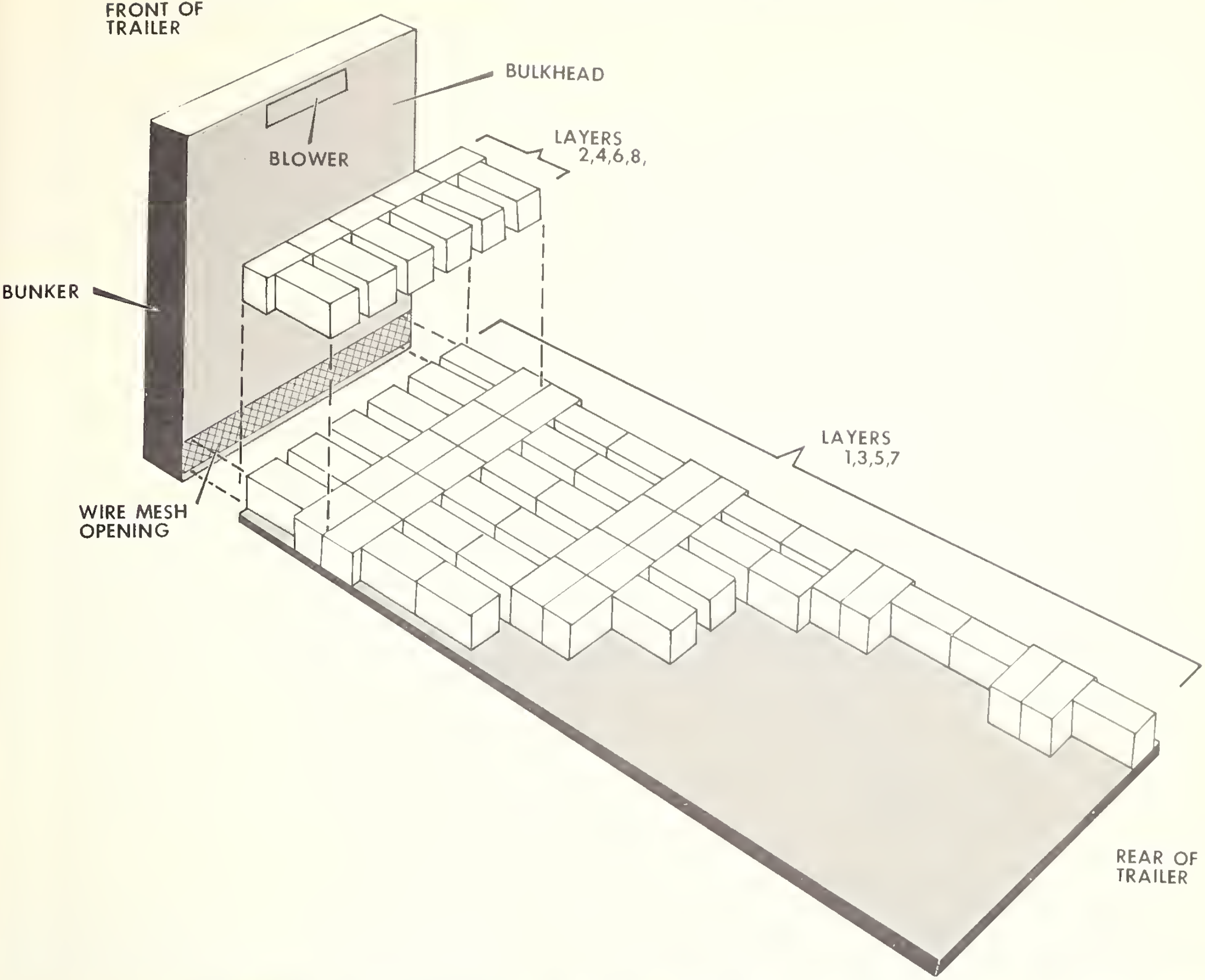


FIGURE 3.—Method for laying off the modified bonded-block loading pattern.

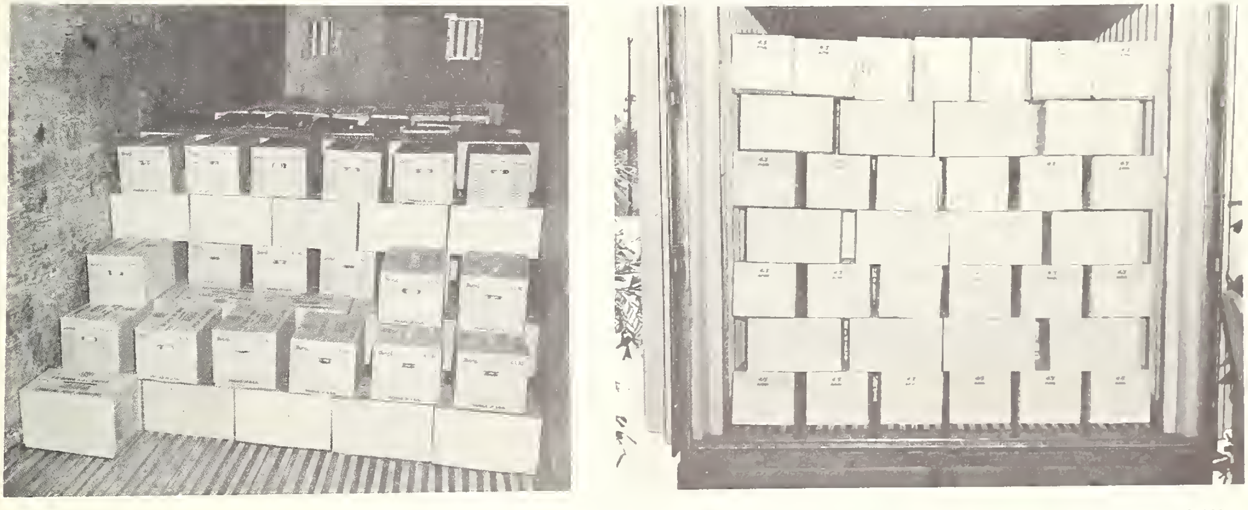


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FIGURE 4.—(A) Partially completed stacks showing the method of building the modified bonded-block pattern. Top layer boxes are spaced to allow vertical entrance air channels. The 6-by-5 pattern is used for trucks with a wide loading space. (B) Completed stack in the 6-by-4 pattern used for trucks with a narrow loading space. Top layer is stacked tight on last two stacks to add stability at rear of load.

# RESULTS OF TESTS

## Air Circulation

In the tight-stacked loads under ventilation, most of the air moved over the top of the load and out the back vent doors (fig. 5). In refrigerated tight-stacked shipments, most of the air discharged from the blower outlet above the load moved down the sidewalls and rear of the load and returned to the evaporator through the channels in the floor.

When ventilated loads were stacked in the modified bonded-block pattern, air moved from front to rear of the trailer through the channels, as shown in figure 2A. Air velocity averaged 225 feet per minute at the rear stack in all channels when the vehicle moved at 50 miles per hour.

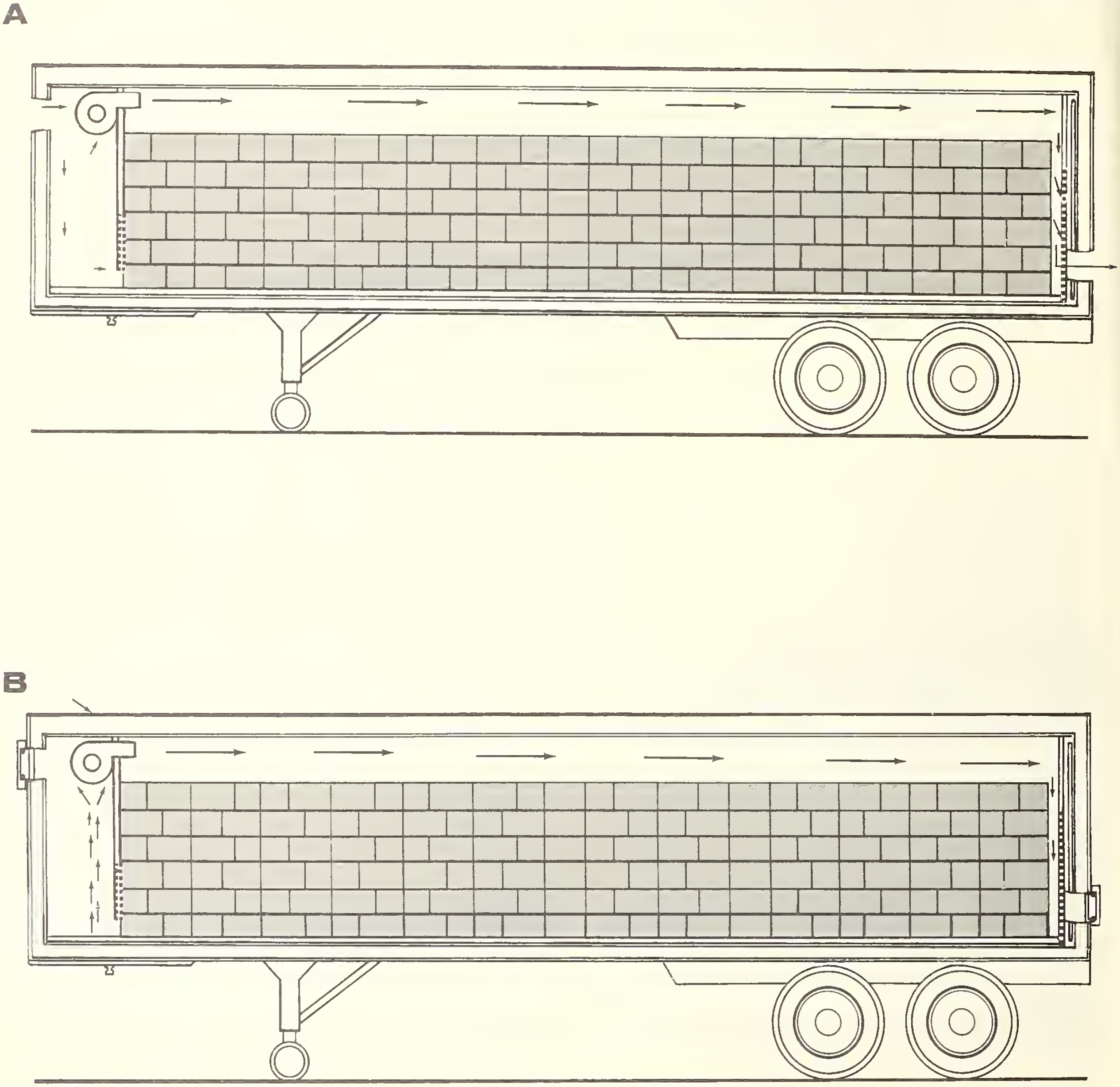

FIGURE 5.—Perimeter air circulation patterns in tight-stacked loads. (A) Ventilated load—*tight* top layer, blower *off*, vent doors *open*. (B) Refrigerated load—*open* top layer, blower *on*, vent doors *closed*.

In refrigerated loads stacked in this pattern, the air discharged from the blower above the load entered the channels through the open-stacked top layer and rear stack and returned to the evaporator through the interconnecting channels, as shown in figure 2B. Air velocity through the load channels averaged 250 feet per minute. (For an example of air velocities through channels in ventilated and refrigerated airflow loads, see fig. 6.)

## Product Refrigeration

One of the more important advantages of the new pattern is improved product refrigeration. Table 1 lists the transit temperatures of three test shipments, each using a different type of protective service.

In one ventilated shipment, the average pulp temperature at loading was 80° F. This temperature was reduced to 69° during 53 hours in transit. Outside air temperature averaged 62° during this period. In another test in which an ice bunker and blower supplied the refrigeration, the average commodity temperature at loading was 90°, and after 36 hours the commodity temperature had been reduced to 65°. The average outside air temperature during this period was 70°.

**Table 1.**—*Fruit and air temperatures in trailer shipments of Florida oranges and grapefruit in 4/5-bushel corrugated fiberboard boxes loaded in the modified bonded-block pattern* [1]

| Protective service | Fruit temperature at loading | | Average outside air during transit | Time in transit | Fruit temperature at unloading | | Average temperature reduction in transit |
|---|---|---|---|---|---|---|---|
| | Average | Range | | | Average | Range | |
| | *° F.* | *° F.* | *° F.* | *Hr.* | *° F.* | *° F.* | *° F.* |
| Ventilation | 80 | 78–82 | 62 | 53 | 69 | 67–73 | 11 |
| Ice bunker and blower | 90 | 89–94 | 70 | 36 | 65 | 59–73 | 25 |
| Mechanical refrigeration | 75 | 71–78 | 62 | 84 | 42 | 41–45 | 33 |

[1] Three test shipments from Florida to New York City.

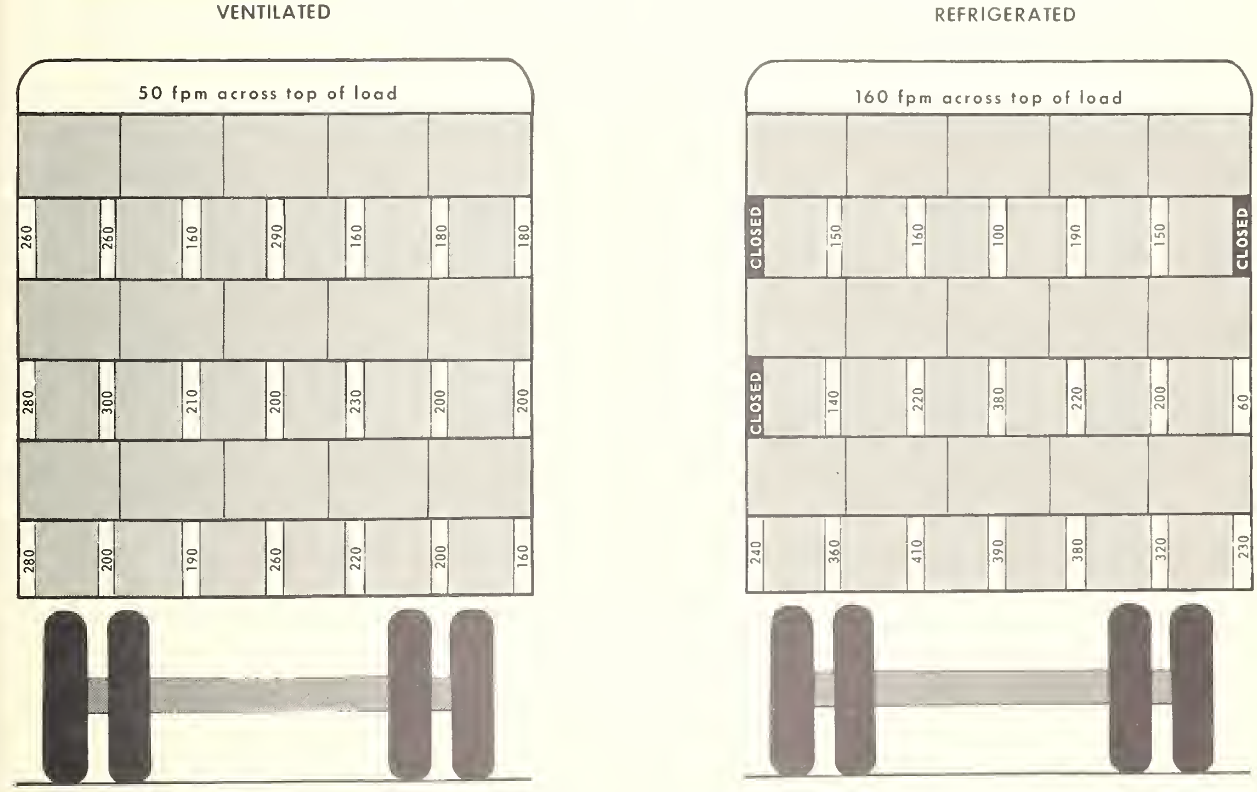

**Figure 6.**—Air velocities in channels of the rear stack of ventilated and refrigerated modified bonded-block loads. Velocities in feet per minute (f.p.m.).

The third test moved under mechanical refrigeration by piggyback. Fruit temperature at loading averaged 75° F. After 84 hours in transit, the average commodity temperature had been reduced to 42°. During this period the outside air temperatures averaged 62°.

Control shipments to determine the comparative effectiveness of product refrigeration were not made with tight-stack loads. The new pattern was accepted so quickly and completely by citrus fruit shippers using the fiberboard box that no shipper was willing to revert to the older method for test purposes.

The modified bonded-block pattern was used in a trailer load of grapefruit in fiberboard boxes shipped from Florida to Switzerland by highway, piggyback, and containerized ocean transport. The new stacking pattern made it possible to maintain uniform fruit temperature throughout the load during the 19-day trip. Also, no load shifting or container or produce damage occurred (*1*).

## Commodity and Container Damage

Shipping experience with the modified bonded-block pattern showed that its stability reduced load shifting and physical damage to both commodity and container. In all test shipments with the pattern, no containers were damaged seriously enough to be rejected by the consignee.

The system of interconnecting channels in this pattern provides a safeguard against complete blockage of air circulation in a shifting load. If a part of the load should shift slightly and block some of the channels, air circulation through the center of the load would continue through the vertically and horizontally connected channels.

## Trade Acceptance

During the 1962–63 season, more than 22 million ⅘-bushel corrugated fiberboard boxes of oranges and grapefruit were shipped from Florida (*4*). The pattern has been widely accepted by shippers, carriers, and receivers as an improved method of loading Florida oranges and grapefruit to obtain better fruit cooling during transport. It is estimated that 90 percent of this fruit was stacked in the modified bonded-block pattern.

Before development of the new load pattern, many shippers would not use the ⅘-bushel fiberboard box because of previous experience with unfavorable fruit temperature in tight-stacked loads. Wirebound crates of ⅘- and 1⅗-bushel capacities were widely used because the openings between the slats permitted circulating air to contact the fruit.

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